UDC 621.397.132

BBC

1969
THE QUEEN'S AWARD
TO INDUSTRY

RESEARCH DEPARTMENT

REPORT

TELEVISION SYSTEM I:
a proposed specification for group delay at high video frequencies

No. 1972/39

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

TELEVISION SYSTEM I: A PROPOSED SPECIFICATION FOR GROUP DELAY AT HIGH VIDEO FREQUENCIES

Research Department Report No. **1972/39**
UDC 621.397.132

This Report may not be reproduced in any form without the written permission of the British Broadcasting Corporation.

It uses SI units in accordance with B.S. document PD 5686.

P. Rainger

Head of Research Department

R.W. King, B.Eng., Ph.D., D.I.C.
A. Brown, C.Eng., M.I.E.E., M.I.E.R.E.

(EL-72)

Research Department Report No. 1972/39

TELEVISION SYSTEM I: A PROPOSED SPECIFICATION FOR GROUP DELAY AT HIGH VIDEO FREQUENCIES

Section	Title	Page
	Summary	1
1.	Introduction	1
2.	Subjective tests	1
	2.1 Experimental arrangement	1
	2.2 Description of tests	2
	2.2.1 Pictures	2
	2.2.2 Assessment of the onset of impairment	2
	2.2.3 Ratings on the EBU impairment scale	2
	2.3 Analysis of Results	2
	2.3.1 Onset of impairment	2
	2.3.2 Impairment ratings	3
3.	Derivation of the proposed specification	3
4.	A test signal for evaluating group delay distortion	3
5.	Conclusions	5
6.	References	5

November 1972

Research Department Report No. 1972/39
UDC 621. 397. 132

TELEVISION SYSTEM I: A PROPOSED SPECIFICATION FOR GROUP DELAY AT HIGH VIDEO FREQUENCIES

Summary

The specification described is based on the results of subjective tests in which particularly critical still pictures were subjected to group delay variations at frequencies above the colour subcarrier. Large variations can be tolerated towards the top of the band: there is little impairment when the delay rises from nearly zero at 4·4 MHz to 1·1 μs at 5·5 MHz. It is shown that the 10-T chrominance pulse can be used for testing this type of distortion, and a template for system evaluation is described.

1. Introduction

The specification for group-delay distortion in a System I television hypothetical reference circuit sets a limit of ± 100 ns on the chrominance-luminance delay inequality[1], but this refers only to the delay at the frequency of the colour subcarrier relative to that at low frequencies. Group-delay variations in the lower and middle part of the video band can be measured as distortions in the response of a 2T pulse. The corresponding 'K' rating, together with the specification of the relative delay at the subcarrier frequency, define the permissible delay variations up to the subcarrier frequency with sufficient accuracy.

The need for a specification for delay variations above the subcarrier frequency has arisen in a study of filters[2] for use in digital p.c.m. codecs operating with a sampling rate close to the Nyquist limit. These filters have a very sharp cut-off rate, with correspondingly large group-delay variations at high frequencies. It is desirable to know what variations can be permitted, in order to assess the complexity of the phase correction circuits required.

The specification developed in this report is based on tests using a monotonic increase of delay across the upper sideband of the chrominance channel. Assuming that an equal advance characteristic has corresponding subjective effects, we are able to form a group-delay envelope for a given subjective impairment. Fortunately, the PAL system permits, with a properly-adjusted decoder, quite large distortions of this type to be present[3]. The distortion causes a reduction of saturation, and in severe cases a change of hue, on vertical edges; the general subjective impression is a smearing of highly saturated vertical coloured edges.

In the subjective tests, still pictures containing highly saturated vertical detail were subjected to different amounts of group-delay distortion of the type described above. In the principal test the observers judged the distorted pictures on an impairment scale. From these judgements we are able to construct limiting group-delay characteristics corresponding to the various impairment grades.

Direct group-delay measurements can seldom be carried out on a practical system, so consideration is given to a test which evaluates the group-delay distortion by measurements on the standard 10T chrominance pulse. Computer analysis and direct measurement was used to show that this pulse was suitable for examining the delay distortion at frequencies above about 5 MHz, but accurate measurement is required to obtain meaningful results.

2. Subjective tests

2.1 Experimental arrangement

A block diagram of the experimental arrangement is shown in Fig. 1. The group-delay inserter was an active unit based on a circuit developed for use in a television standards converter[4]. It allowed a greater range of delay characteristics to be obtained than could conveniently be achieved with passive all-pass networks. In addition to this unit, two passive networks were used to improve the delay equalisation up to the subcarrier frequency, and the amplitude equaliser shown in Fig. 1 compensated for a fall-off over the video band of about 2 dB, caused by the group-delay inserter.

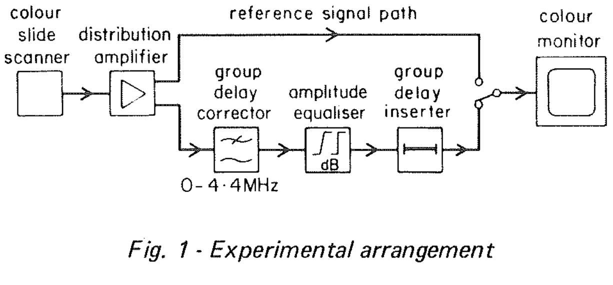


Fig. 1 - Experimental arrangement

Twenty-one delay characteristics were available. These can be grouped into three sets of seven. Those forming the the first set, A, are shown in Fig. 2. Sets B and C had a similar shape, but the peaks were shifted down in frequency by 0·25 and 0·5 MHz respectively, while still maintaining the delay within about ± 50 ns up to subcarrier frequency. We shall signify each characteristic by the letter A, B, or C, denoting its set, and a number from 1 to 7 corresponding to a progressive increase in the delay. Thus, for example, the sharpest increase in delay, which rises to 1·1 μs at 5·0 MHz, is designated by C7.

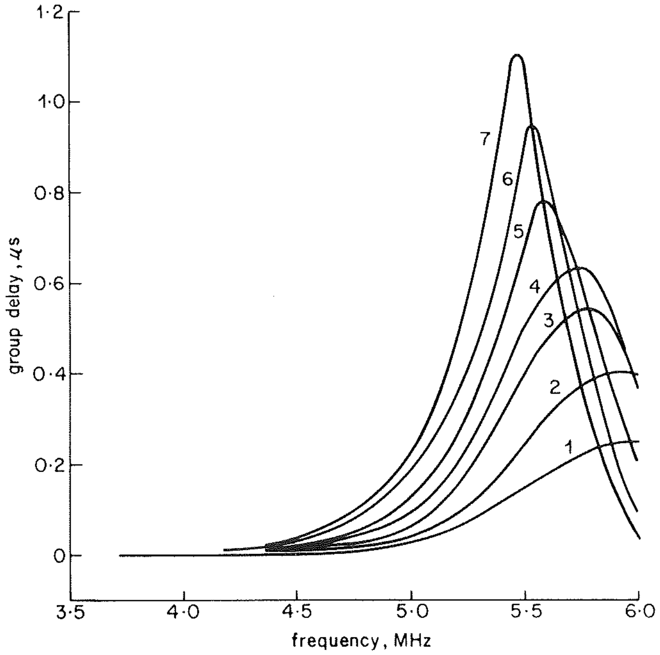


Fig. 2 - Group delay characteristics A 1 - A 7

2.2 Description of tests

2.2.1 Pictures

Prior to the tests the monitor brightness and contrast were adjusted to give a pleasing picture, in fairly low ambient lighting conditions. The nine observers were technical staff having various degrees of experience in judging picture impairments. They carried out the tests individually, and were seated at a viewing distance of five times the picture height.

Three colour slides from a flying-spot scanner were displayed on the monitor. Two of them, viz., "boy with toys" and "camera channel", the latter being a line diagram, contained highly saturated detail; the third, "girl with scarf", could be regarded as representing a more typical programme picture.

2.2.2 Assessment of the onset of impairment

In this test the observer was asked, for each picture and each set of delay characteristics, to increase the delay until he was just able to perceive an impairment. He was asked to ignore the slight change in saturation in broad areas of the picture caused by small differences in the amplitude response of the group-delay inserter and, if he expressed difficulty in identifying the impairment, it was suggested that he should look for edge effects.

2.2.3 Ratings on the EBU impairment scale

For the "boy with toys" slide alone, the observer was asked to assess the effect of various delay characteristics and to grade his assessment according to the EBU 6-point impairment scale.

1 Not perceptible
2 Just perceptible
3 Definitely perceptible but not disturbing
4 Somewhat objectionable
5 Definitely objectionable
6 Unusable

Eleven different characteristics were used, presented in random order, and several were repeated to ascertain the consistency of each observer's judgements.

Throughout both tests the observer was allowed to switch to the unimpaired picture for comparison, and was allowed as much time as he wanted to make his decision. (On average the tests took about twenty minutes.)

2.3 Analysis of Results

2.3.1 Onset of impairment

In the case of the "girl with scarf" picture, no picture impairment was noticed by any observer, even when the maximum delay available was inserted.

For the other two pictures the results of the tests enable us to determine three group-delay characteristics which may be regarded as corresponding to grade 2 impairment. To obtain these we make several assumptions. Firstly, the delay characteristics are regarded as being selections on a linearly increasing scale, so that the range settings 1–7 can be taken as belonging to a continuum, and fractional settings obtained by interpolation are permitted for purposes of analysis. This allows us to specify a characteristic as, for example, A 5·4, which would represent an interpolation between curves A5 and A6 in Fig. 2. Secondly, if the observer could not perceive any distortion we assume he would perceive it on a hypothetical range 8. Thirdly, it must be remembered that an observer recording delay characteristic 1 could possibly perceive impairment with even lower distortion.

For each set of delays (defined by the letter coding), we can calculate from the subjective test data the mean delay characteristic for which impairment becomes just perceptible. The results, and the standard deviation for each set of delays, are shown in Table 1. The reduction in standard deviation for the more severe delay characteristics is not unexpected, because the impairment is easier to identify in these cases. The "camera channel" picture is slightly more sensitive to lower delays, probably because the high-frequency colour information is more clearly defined in this picture than in the more cluttered "boy with toys" picture.

TABLE 1

The Group-Delay Characteristics for which Just-Perceptible Impairment Occurs

SET	"boy with toys"			"camera channel"		
	A	B	C	A	B	C
Mean Standard deviation (9 observers)	6·2 2·1	4·2 1·5	2·2 1·1	5·4 2·0	3·1 1·6	2·3 0·7

2.3.2 Impairment ratings

Whereas the results in section 2.3.1 refer only to the onset of visible impairment, the second series of tests (described in Section 2.2.3) provided data on the distortion required to produce various grades of impairments. The results for the nine observers are quite consistent; only about 10% of the judgements for any particular delay characteristic are more than one impairment grade different from the mean value. The mean impairment grades ascribed to the eleven delay conditions used are given in Table 2.

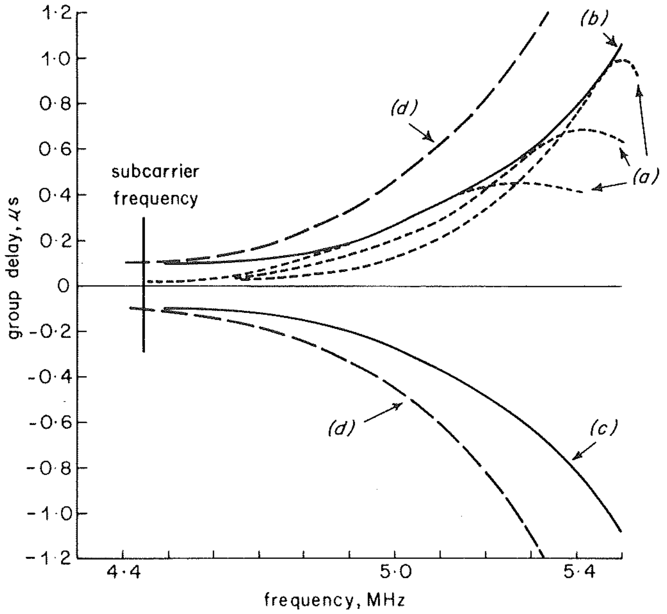


Fig. 3 - Group delay specification for impairment grades 1·5 and 2

(a) - - - - - - - - - - characteristics A6·3, B4·5, C1·7
(b) and (c) ———————— limit for grade 1·5 impairment
(d) — — — — — limit for grade 2 impairment

TABLE 2

Mean Impairment Grades for Eleven Conditions of Group Delay Distortion for "Boy with Toys"

Delay characteristic	A3	A5	A7	B1	B3	B5	B7	C1	C3	C5	C7
Mean impairment grade	1·2	1·2	1·6	1·2	1·2	1·6	2·4	1·2	2·6	3·1	3·6

The results of the tests are fairly consistent with those described in Section 2.3.1. and listed in Table 1.

3. Derivation of the proposed specification

The proposed specification is defined for grade 1·5 impairment from the results given in Table 2. Interpolation of these results indicates that grade 1·5 impairment is obtained for characteristics A6·3, B4·5, and C1·7. Fig. 3, curves (a), shows these characteristics, assuming linear interpolation between the "integral value" delay characteristics. The specification [Fig. 3, curve (b)] is determined by the envelope of these curves, which passes through 100 ns delay at 4·43 MHz, to accord with the CCIR specification at this frequency. To complete the proposed specification we assume that a corresponding advance characteristic [Fig. 3, curve (c)] would produce a subjective impairment comparable with that produced by a delay characteristic. Thus, a delay or advance of 1·1 μs can be tolerated at the edge of the video band without more than grade 1·5 impairment.

A second envelope, derived in the same way for grade 2 impairment, is also shown in Fig. 3, curve (d).

4. A test signal for evaluating group delay distortion

As it is often impracticable to measure directly the total group delay of a system, it is desirable to use the more convenient but indirect method employing a test pulse to evaluate the group delay in the upper video band. A signal having significant frequency components in this band is the 10 T chrominance pulse.[5] The amplitude spectrum of this pulse is about 35 dB down at 4·43 ± 1 MHz, and it is therefore not very sensitive to delay variations in the region of 5·5 MHz. However, since the proposed specification is less stringent in this region, the distortion of the pulse shape may be expected to provide a reasonable measure of the subjective impairment caused by the high-frequency variations.

If group-delay variations occur in the region of 3·5 MHz, to which the 10 T chrominance pulse will be insensitive, these can be evaluated by measuring the distortion of the 2 T luminance pulse.

The currently used insertion test signal I contains a composite pulse in which the chrominance pulse is super-

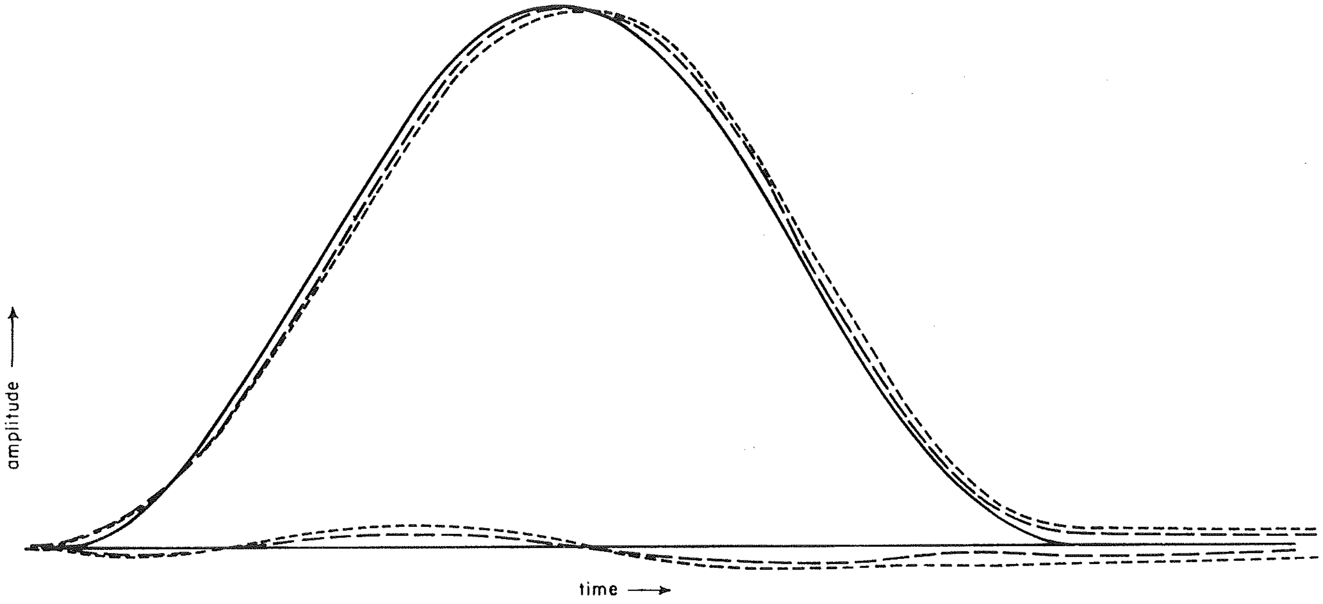


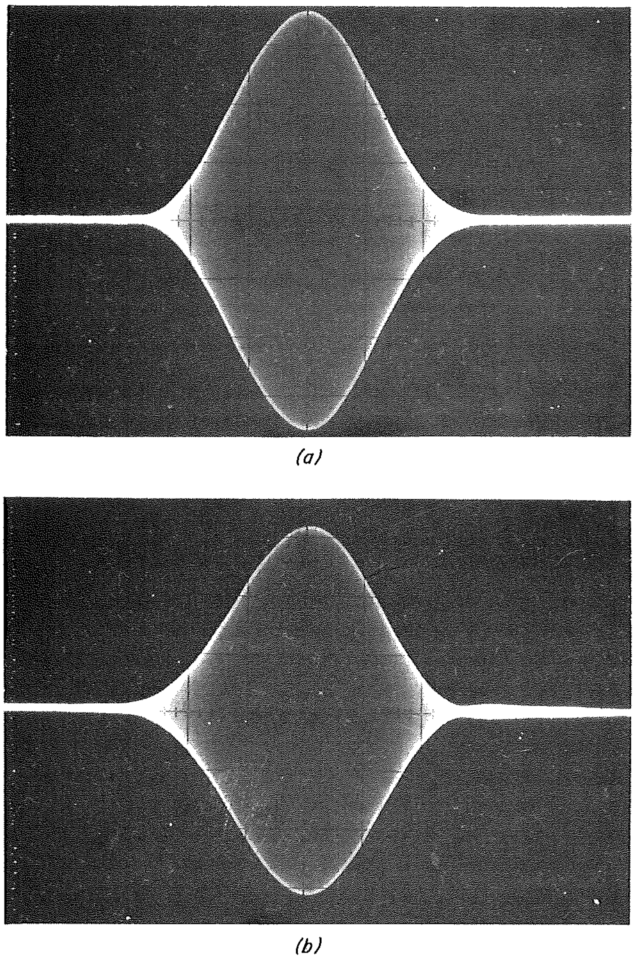
Fig. 4 - Computed envelope of 10-T composite luminance/chrominance pulse delayed by characteristics corresponding to impairment grades 1·5 and 2

——— undistorted pulse

— — — effect of group-delay characteristic for impairment grade 1·5

- - - - - - - effect of group-delay characteristic for impairment grade 2

imposed on a 10 T luminance pulse, to facilitate measurements of the relative gain and delay of the chrominance frequency band compared with lower frequencies. It is useful to consider if this composite pulse could be used to evaluate the effects of the type of group-delay variations with which we are now concerned. The responses resulting when the composite pulse is subjected to various types of group-delay distortion have been computed using a Fourier analysis programme. It proved simpler for computation purposes to use a 10·2 T pulse so that exactly nine subcarrier cycles were contained within the pulse envelope, but this should have no significant effect on the conclusions. Fig. 4 shows how the envelope of this pulse is distorted by group-delay characteristics similar to the limiting curves Figs. 3b and 3d, corresponding to impairment grades 1·5 and 2. The most noticeable distortion is an elongation of the trailing edge of the pulse, together with a change of shape of the main body of the pulse and a small asymmetry of the base line within the main envelope. The latter is important because it could be wrongly interpreted as a delay inequality between the subcarrier frequency and the low-frequency luminance components, i.e., the "delay inequality". Fig. 5 illustrates the distortion, for a practical measurement of the chrominance component* of the pulse distorted by delay characteristic B5 (approximately impairment grade 2). Comparison with the undistorted pulse shows that the delay causes the leading edge to rise more slowly and the trailing edge to fall rapidly before elongating into the tail. The centre of the pulse is largely undisturbed by the group-delay distortion; the delayed high-frequency components are concentrated into the extremities of the pulse.



(a)

(b)

Fig. 5 - Chrominance component of a 10-T composite luminance/chrominance pulse

(a) Unimpaired pulse

(b) Pulse distorted by group-delay characteristic B5.

---

*A BBC Gain and Delay Tester type TE1/503 was used to separate the chrominance component from the composite pulse.

The chrominance component alone provides an indication of the relative delay over the chrominance bandwidth only. An elongated trailing edge indicates a delay variation, and its amplitude and length depend on the delay characteristic. If the composite luminance/chrominance pulse has an asymmetrical base line, but no tail, there is a finite delay at the subcarrier frequency. Fortunately, the experiments showed that for a particular impairment grade the base line asymmetry associated with the high-frequency delay is very much less than that due to chrominance-luminance delay at the subcarrier frequency, so the high-frequency effects can be dissociated to a reasonable degree from the effects at the subcarrier frequency.

Thus the assessments of both delay inequality and high-frequency delay can be made independently from the composite pulse, provided the subjective impairment grade of the high-frequency delay is not very much larger than that of the delay inequality. From the computed pulse envelopes we can define the tail amplitudes for impairment grades 1·5 and 2. These are shown in Fig. 6 in the form of a template which includes an equal elongation of the leading edge of the pulse corresponding to a relative advance over the upper vision band. The scale of the displayed pulse is provided by the half-amplitude points shown on the template.

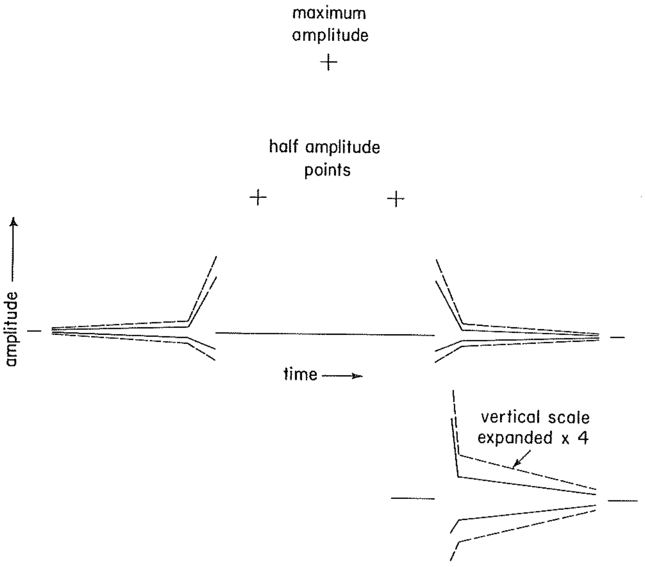


Fig. 6 - Template for 10-T composite luminance/chrominance pulse, for evaluating group-delay distortion in the upper video band

——— impairment grade 1·5
- - - - impairment grade 2

5. Conclusions

We have proposed a specification for the total permissible group-delay variation in the upper video band of 625-line System I television transmissions for grade 1·5 impairment.

Large delay variations at the top of the band can be tolerated. The specification is based on the results of subjective tests in which one particularly critical picture containing saturated detail was subjected to varying degrees of delay distortion. The impairment of this picture was hardly perceptible for delays rising from less than 100 ns at the subcarrier frequency to 1·1 μs at 5·5 MHz. For a picture with a more typical saturation and detail content, a delay rising to 1·1 μs at 5·0 MHz could be tolerated without visible impairment.

The high-frequency delay variations can be evaluated by measuring the trailing edge of a 10 T composite luminance/chrominance pulse, and a template to evaluate this has been described. The effects of group delay variations over the whole video band can thereby be evaluated from the responses of standard test signals. The subjective influence of the group-delay distortion in the presence of other distortions has not been considered.

It is hoped that this specification will be useful in defining a realistic limit for systems which introduce large high-frequency group-delay variations.

6. References

1. CCIR New Delhi 1970. Vol. V, Pt. 2, Recommendation 451–1.

2. Digital video: Reduction of sampling frequency to 11·9 MHz. BBC Research Department Report No. 1972/36.

3. SIMS, H.V. 1969. Principles of PAL colour television. London, Iliffe, 1969.

4. Field store standards conversion: equalisers for ultrasonic quartz delay lines. BBC Research Department Report 1971/36.

5. WEAVER, L.E. 1971. Television measurement techniques. IEE Monograph series, No. 8, Cambridge University Press, 1971.

6. LEWIS, N.W. *and* ALLNATT, J.W. 1968. Subjective and objective impairments in television pictures. IEE Conference Publication No. 46.

Printed by BBC Research Department, Kingswood Warren, Tadworth, Surrey